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Eric J. Holcomb
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January 22, 2019

Mr. Justin Coughlin, Project Manager
USEPA REGION 5
77 West Jackson Boulevard
Mail Code: AT-18J
Chicago, IL 60604-3507

Dear Mr. Coughlin:

Re: **Flow Rate Audit of the Semi-continuous Metals Analyzer and Collocated Transfer Standard Audit of the Sonic Wind Sensor at the Hammond-Lakeview Street Monitoring Site**

As requested by Scott Hamilton (EPA Region 5), staff members from the Quality Assurance Section performed a flow rate audit of the Cooper Environmental Services Model 625 Xact Semi-continuous Metals Analyzer and a collocated transfer standard audit of the Met One sonic weather sensor located at the Hammond-Lakeview Street monitoring site. On October 30, 2018 Jake Brehmer and James Roane met with Scott Hamilton to perform the flow rate audit of the Xact metals analyzer and to install a mechanical R. M. Young wind sensor and data logger to collect comparative wind speed and wind direction data with the on-site ultrasonic unit. On November 9, Roger Osburn and James Roane met with Scott Hamilton to remove the R. M. Young wind sensor and data logger.

Audit Results

Flow Rate Audit

Scott Hamilton operated the Xact unit's front panel to display the ambient environmental data parameters (ambient temperature and barometric pressure) and volumetric flow rate collected by the Model 625 Xact analyzer. Prior to starting the audit, leak checks of the pneumatic system were performed by Scott Hamilton with the results indicating that the unit was functioning satisfactorily within its operational limits. Jake Brehmer performed the audit of the flow rate and environmental parameters at the sample inlet downtube (TSP sample inlet was removed). The parameters required for calculating the flow rate were measured using the following test equipment certified by the IDEM QA Certification Facility:

- Chinook Engineering Streamline Flow Transfer Standard, serial number 010402, certified August 6, 2018;
- Novalynx M2 Series digital barometer, serial number 1702000023, certified September 12, 2018;
- VWR Scientific Model 100A temperature probe, serial number C470320, certified August 1, 2018.

The comparison of the observed values from the Xact analyzer and the values from QA test equipment, along with the leak check results, is shown in Table 1. The difference column of Table 1 is the comparison of the observed value to the IDEM QA value (the "true value"). The calculation of the IDEM QA flow rate value is presented in Appendix A.

Table 1. Xact Model 625 Audit Results.

Data Parameter	Observed value	IDEM QA value	Difference
Ambient Temperature, °C	14.1	14.1	0.0
Barometric Pressure , mm Hg	739.9	743.3	-3.4
Flow Rate, LPM	16.7	16.65	+0.3%
Leak check #1 value	125.7		
Leak check #2 value	48.0		

As there are no regulatory acceptance audit criteria for a continuous TSP low-volume sampling unit, the audit results were compared to accuracy acceptance criteria for a continuous $PM_{2.5}$ local conditions unit (Table 2) [ref: Appendix D, Quality Assurance Handbook for Air Pollution Measurement Systems Volume II: Ambient Air Quality Monitoring Program, EPA-454/B-17-001, January 2017].

Table 2. $PM_{2.5}$ Audit Evaluation Criteria

Evaluation Criteria	Acceptable Range
Temperature Audit difference, ΔT_a	*-2.1 °C < ΔT_a <2.1 °C*
Pressure Audit difference, ΔP_a	*-10.1 mm Hg < ΔP_a < 10.1 mm Hg*
Flow rate difference, ΔQ	*-4.1% < ΔQ < 4.1%*

When compared to the evaluation criteria of Table 2, the QA audit results indicate the Xact unit is collecting acceptable ambient temperature and pressure and the flow rate is operating within the acceptable range.

Meteorological audit

The on-site wind sensor is a Met One Model 50.5 Sonic Wind Sensor with an attached Met One model 3269 automatic directional alignment module. The sonic unit is mounted on free-standing, collapsible section mast. The evaluation was conducted using a mechanical R. M. Young Model 05305-AQ Wind Monitor (serial number 40625) to collect collocated resultant wind speeds and directions. A Campbell Scientific CR200 data logger and a laptop with the Campbell Scientific PC200W software were used to collect and view vectored wind speed and wind direction data. The wind speed and the wind direction bench linearity checks of the Model 05305 Wind Monitor were performed on October 29, 2018 with satisfactory results. The collocated transfer standard was installed on October 30th and removed from the site on November 9th. Raw wind speed and wind direction data from the mechanical wind monitor and the sonic wind sensor were exchanged between EPA and IDEM. Graphical representation of the collected data is provided in Appendix B.

The hourly wind parameter data from both units were uploaded into a Microsoft Excel spreadsheet for analysis. A wind parameter difference was calculated for each hour using

wind parameter difference = (sonic wind value) – (mechanical wind value).

The mean and standard deviation of the wind parameter difference was calculated for all hourly data and for all qualified data (data with wind speeds greater than 1 meter per second). The wind speed and wind direction evaluation results are provided in Table 3 with the evaluation criteria provided in Table 4.

Table 3. Comparison of the Sonic Wind Sensor to the Mechanical Wind Monitor

Wind Parameter	Mean Difference (All hourly data)	Mean Difference (Qualified hourly data)
Resultant Wind Speed, $m \cdot s^{-1}$	0.08	0.09
Standard Deviation of the Difference, $m \cdot s^{-1}$	0.100	0.104
Resultant Wind Direction, degrees compass	-1.88	-2.21
Standard Deviation of the Difference, deg compass	3.35	2.98

Table 4. Proposed Audit Criteria for the Sonic Systems [ref: Table 2.2, Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV: Meteorological Measurement, Version 2.0 (Final), (EPA-454/B-08-002 March 2008).

Wind Variable	Average difference	Standard deviation of the Differences	Qualifications
Speed	$\pm 0.25\ m \cdot s^{-1} < 5\ m\ s^{-1}$ or ± 5% or $<2.5\ m \cdot s^{-1}$ above $5\ m \cdot s^{-1}$	$0.2\ m \cdot s^{-1}$	Wind speeds > $1\ m \cdot s^{-1}$
Direction	± 5°	2°	Wind speeds > $1\ m \cdot s^{-1}$

The results indicate that the mean of the wind speed differences and the wind direction differences are within the limits of the proposed evaluation criteria; the standard deviation of the wind speed differences also is within the proposed evaluation of the criteria. The standard deviation of the wind direction differences was greater than the proposed evaluation criteria of 2 degrees compass. The failure to meet this evaluation criteria may be attributed to the swaying of the free-standing mast with the high-center of gravity instrument crossbar and a small rotational movement of the collapsible non-keyed meteorological tower during the monitoring collection period. Overall, the audit results indicate the on-site sonic wind sensor is capable of collecting valid resultant wind speed and resultant wind direction data, which may be used to develop wind rose diagrams to establish wind patterns around the monitoring site.

We appreciate the time and effort put forth by Scott Hamilton in assisting with this evaluation. If you should have any questions or comments regarding this evaluation, please contact me at (317) 308-3257, e-mail address jwicker@idem.in.gov.

Sincerely,

John W. Wicker

John W. Wicker, Chief
Quality Assurance Section
Air Monitoring Branch
Office of Air Quality

JWW/jer

Enclosure
Cc: Scott Hamilton, EPA Region 5

Appendix A. QA Flow Rate Calculation

Model 625 Xact Semi-continuous Metals Analyzer

Analyzer flow rate: 16.7 lpm (Display screen value)

Calculation of the QA indicated flow rate

QA Audit Equipment

- Chinook Engineering Streamline Flow Transfer Standard, serial number 010402, certified August 6, 2018;
- Novalynx M2 Series digital barometer, serial number 1702000023, certified September 12, 2018;
- VWR Scientific Model 100A temperature probe, serial number C470320, certified August 1, 2018.

Data Parameters Collected at sample downtube inlet

- QA ambient temperature: 14.1 °C (287.25 °K)
- QA ambient pressure: 743.3 mm Hg (0.97803 atmospheres)
- Manometer reading: 6.05 inches of water

Chinook Engineering Streamline Flow Transfer Standard Formula [ref: Weitz, Mark A. and Wulff, Shaun S.; *Flow rate measurement in in modern ambient air samplers – how accurate?* Presented at A&WMA 93rd Annual Conference, Salt Lake City, UT; June 2000]

$$\boldsymbol{Q_a = m\sqrt{\frac{(\Delta P)(T_a)}{P_a}} + b}$$

Where

Q_a = actual flow rate, lpm
ΔP = pressure drop across the Chinook orifice, inches H_2O
T_a = ambient temperature, degrees Kelvin
P_a = ambient pressure, atmospheres
m = Chinook FTS slope (for s/n 010402, m = 0.4096)
b = Chinook FTS intercept (for s/n 010402, b = -0.6186)

Substituting into the formula gives

$$Q_a = 0.4096\sqrt{\frac{(6.05)(287.25)}{0.97803}} + (-0.6186)$$

$$\boldsymbol{Q_a = 16.65\ lpm}$$

Appendix B. Collocated Transfer Standard Audit Data Charts

Due to space constraints (buildings, terrain) around the Hammond-Lakeview monitoring site, the area to the west of the site was used to establish a reference point for the R. M. Young Wind Monitor. Longitude and latitude coordinates were collected at the base of the telescoping mast using a GPS. A westerly baseline was setup using the same latitude coordinate as the telescoping mast base and a tripod was setup approximately 100 yards west of the mast base to serve as the reference point.

A crossbar was added to the topmost section of the telescoping mast to allow for the installation of both the sonic wind sensor and the mechanical wind monitor. The crossbar was set in an east-west orientation with the sonic unit installed on the east end of the crossbar and the mechanical unit installed on the west end. The orientation ring for the mechanical wind unit was set such that the mechanical wind unit response from the data logger read 270° when the unit was initially aligned to the reference point.

A string cradle was tied beneath the 90° crossover fitting on the mechanical wind monitor to act as a support point for a plumb bob. The plumb bob was fitted with a sufficient length of string to maintain the orientation of the plumb bob to a specific point on the ground as the telescoping mast is raised (or lowered) corresponding to the orientation of the crossbar. Maintaining the vertical and horizontal orientation of the crossbar is important as the telescoping mast is not keyed and each section can rotate relative to the other sections as the sections are raised (or lowered). The initial plumb bob ground orientation point was marked to identify any shift in the crossbar horizontal orientation during the monitoring period. Prior to lowering the mast to remove the QA unit, it was noted that the plumb bob ground orientation point had shifted approximately an inch from its initial point indicating some horizontal rotation of the crossbar. The response of the QA unit to the reference azimuth is presented in Table 1. The differences observed are considered acceptable as they are within ± 5° of the reference azimuth [ref: Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements Version 2.0 (Final), EPA-454/B-08-002, March 2008].

Table 1. QA Wind Unit Response to the Reference Azimuth.

Azimuth (Expected)	QA Unit Response	Difference,
Installation of unit (October 30, 2018)		
270°	269.0°	-1.0°
Removal of unit (November 9, 2018)		
270°	271.5°	1.5°

The hourly resultant wind speed and wind direction data from the Met One Model 50.5 sonic wind sensor and the R. M. Young Model 05305-AQ Wind Monitor are represented in Figures 1 through 5. Figure 1 compares the hourly resultant wind speed of the two units as a function of data collection time; likewise, Figure 3 compares the hourly resultant wind direction of the two units. Figure 2 compares the respective hourly wind speed of the sonic wind sensor against the mechanical wind monitor; likewise, Figure 4 compares the respective hourly wind direction collected by the sonic unit against the data collected by the mechanical wind unit. Figure 5 is similar to the data contained in Figure 4 but contains some transformed wind direction data. Two data points from the northerly direction in Figure 4 were transformed from (0.87°, 350.0°) and (0.54°, 357.8°) to (360.87°, 350.0°) and (360.54°, 357.8°) respectively. This transformation better reflects the true differences between the resultant wind direction data collected by the two units. When this transformation is allowed, the slope of the data linear regression line approaches the ideal 1:1 comparison line. As seen in all the figures, the results indicate that the two units track well with each other in resultant wind speed and resultant wind direction, but some differences are noted. For example, at higher observed wind speeds, the sonic unit exhibits a larger response than that of the mechanical wind unit. Additional data comparison results are provided in the audit letter.

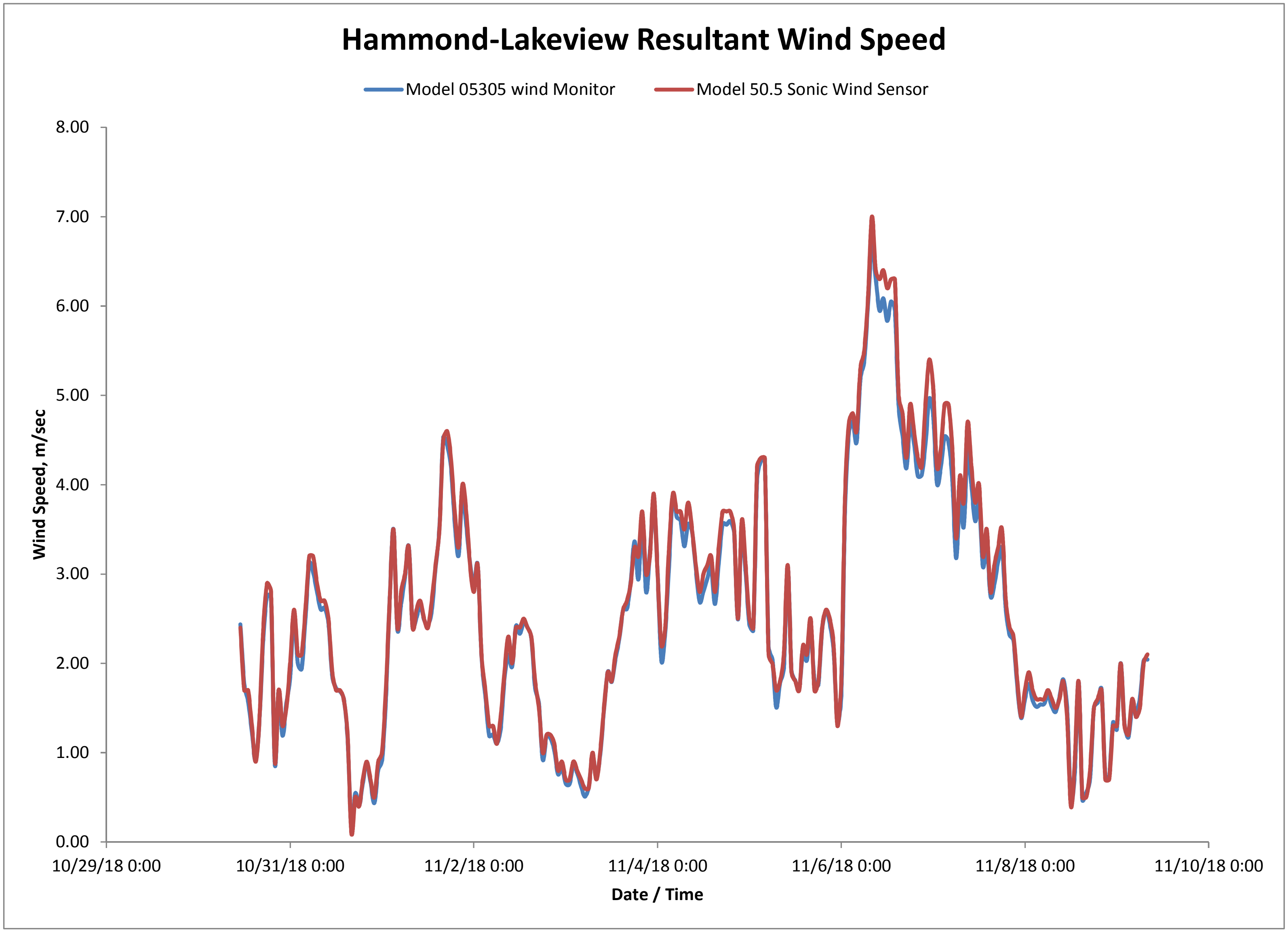

Figure 1. Resultant wind speed comparison of the Model 05305 Wind Monitor and the Model 50.5 Sonic Wind Sensor as a function of time.

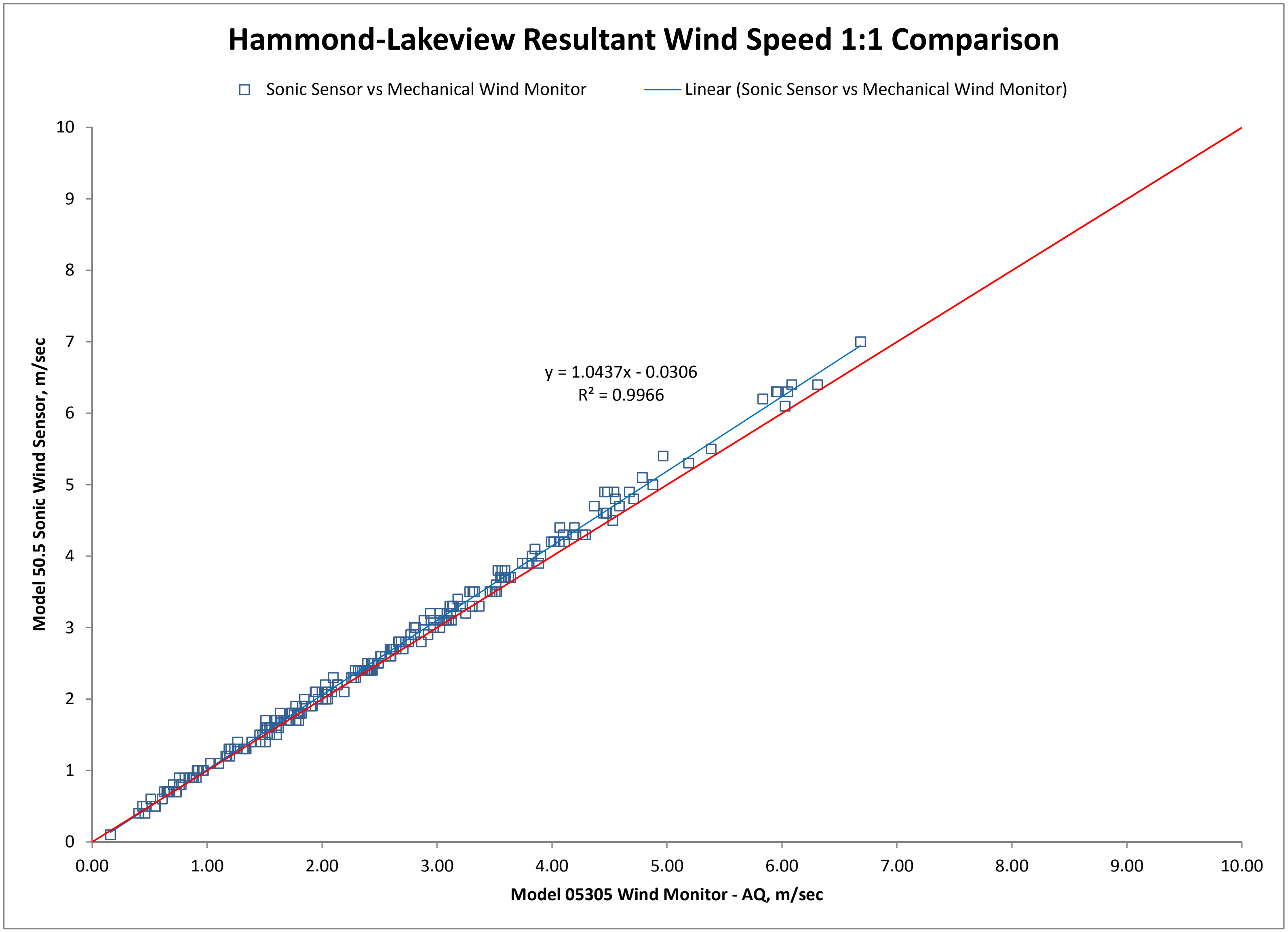

Figure 2. Resultant Wind Speed Comparison of the Model 50.5 Sonic Wind Sensor to the Model 05305 Wind Monitor.

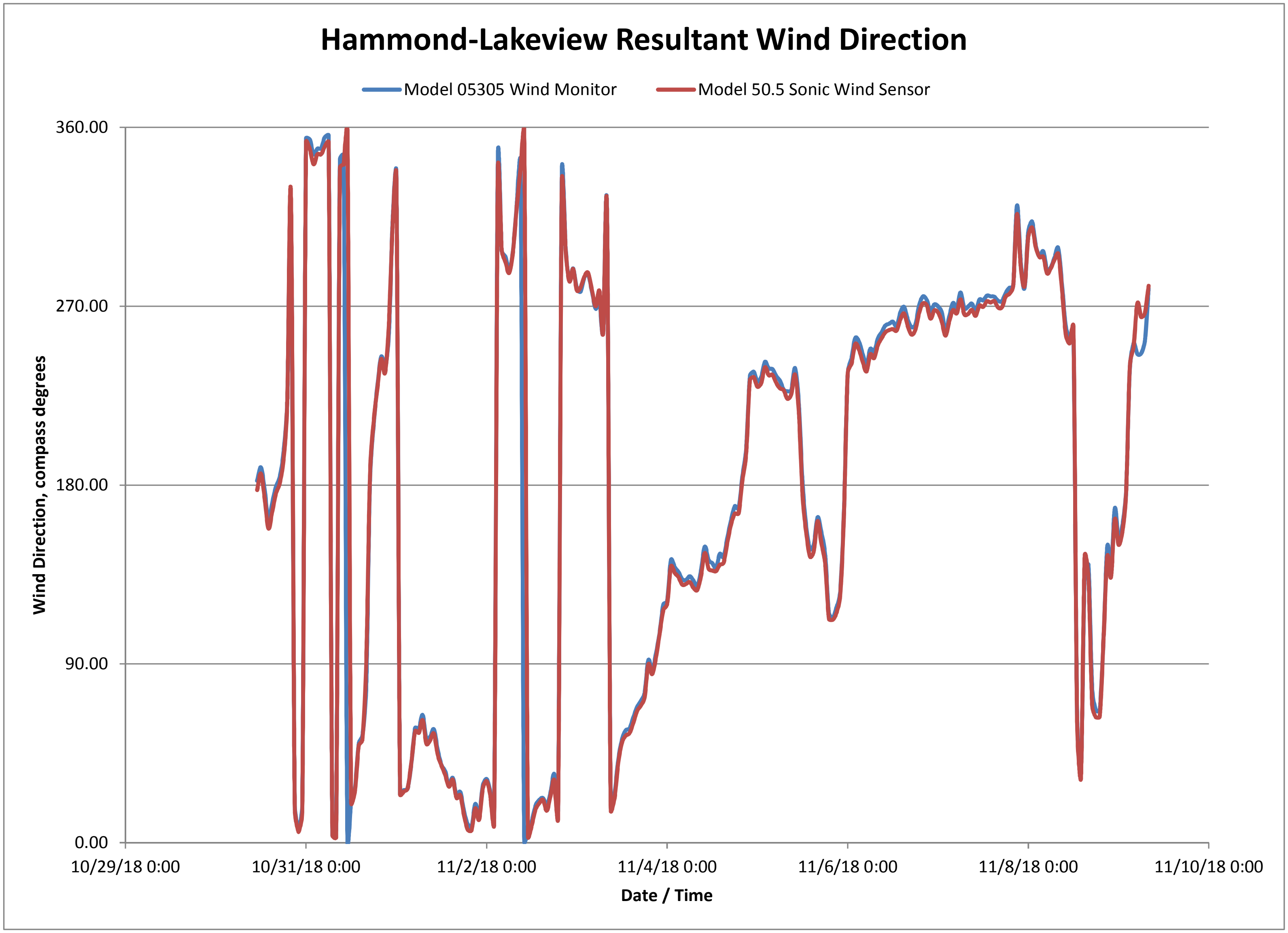

Figure 3. Resultant wind direction comparison of the Model 05305 Wind Monitor and the Model 50.5 Sonic Wind Sensor as a function of time.

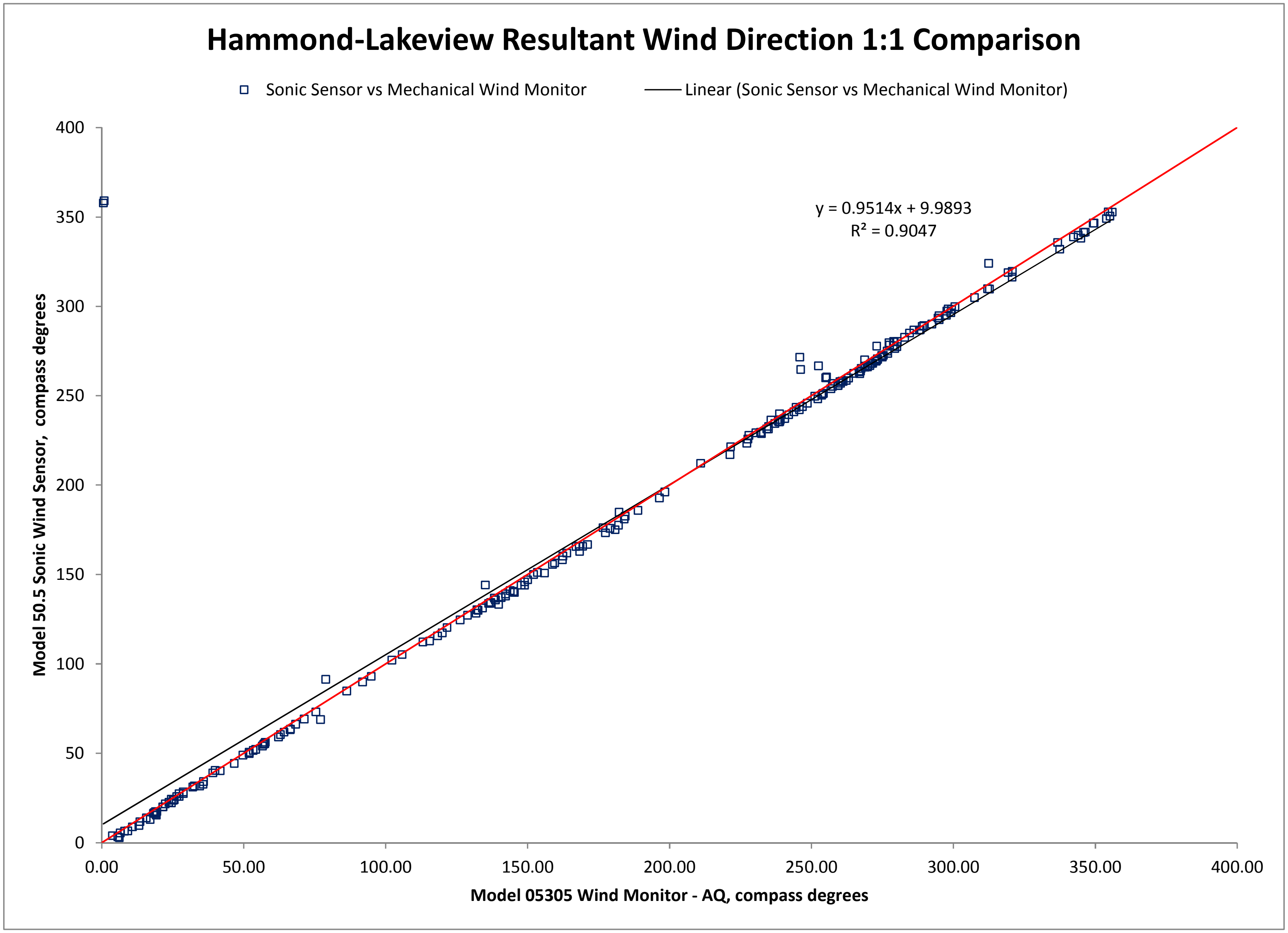

Figure 4. Resultant Wind Direction Comparison of the Model 50.5 Sonic Wind Sensor to the Model 05305 Wind Monitor.

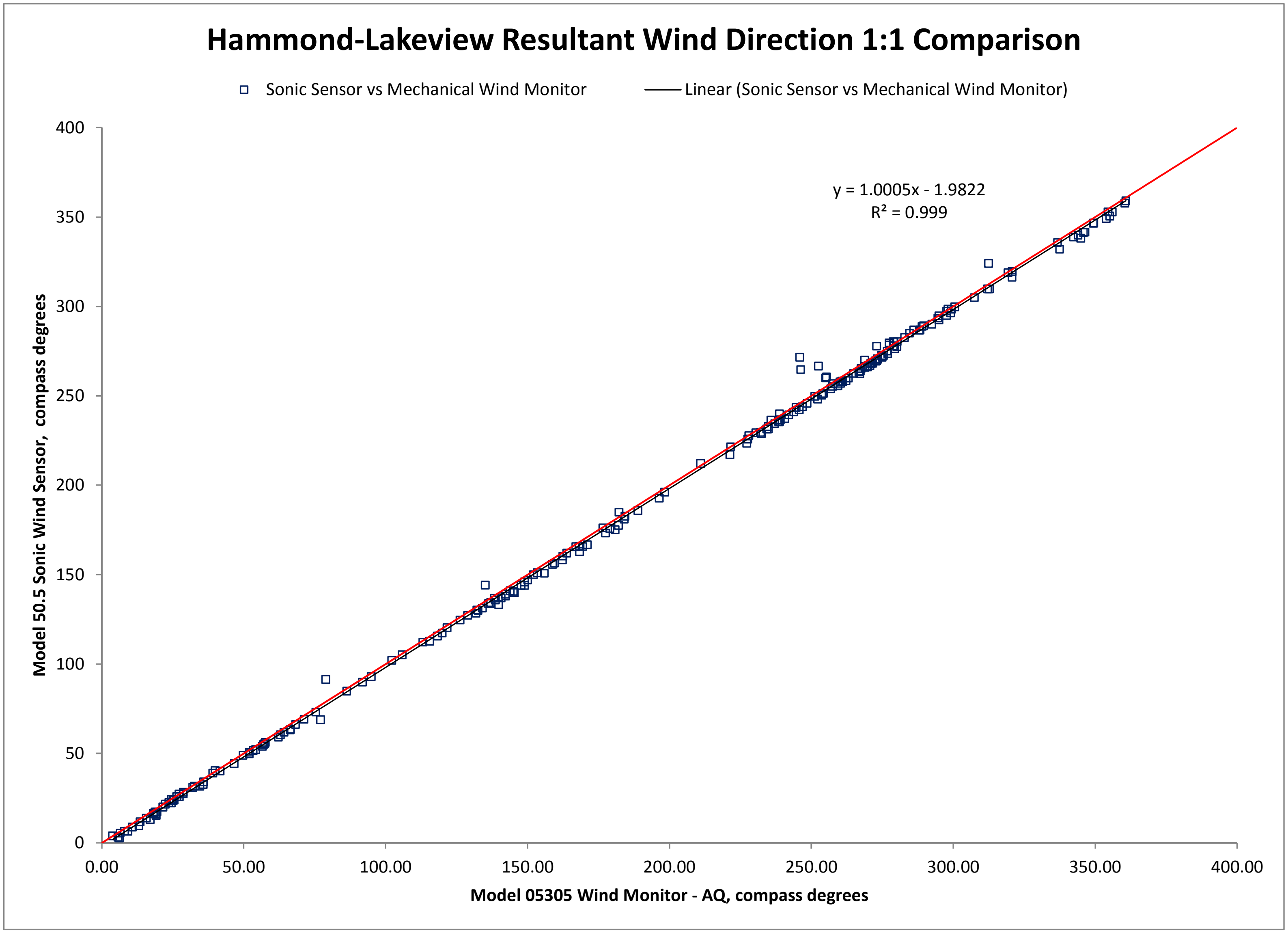

Figure 5. Transformed Resultant Wind Direction Comparison.